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Reports
Simons,
D. B.

EQUATION AND COMPUTER PROGRAM THAT DEVELOP DESIGN TABLES FOR ESTIMATING ROAD SEDIMENT YIELD

Prepared for

USDA Forest Service
Rocky Mountain Forest and Range
Experiment Station
Flagstaff, Arizona

Prepared by

Civil Engineering Department
Engineering Research Center
Colorado State University
Fort Collins, Colorado 80523

D. B. Simons
R. M. Li
T. J. Ward

August, 1978

CER77-78 DBS – RML – TJW 40

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AUTHORIZATION

This research was sponsored by the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station and supported with Colorado State University matching funds. The investigations were conducted in accordance with the Research Agreement No. 16-712.02-CA between the Rocky Mountain Forest and Range Experiment Station and Colorado State University. D. Ross Carder was the authorized project leader for the Rocky Mountain Forest and Range Experiment Station, and Daryl B. Simons and Ruh-Ming Li were the principal investigators for Colorado State University. The period of agreement was from January 10, 1977 to September 30, 1977. In accordance with the study plan, the report on the equations and computer program that develop design tables for estimating road sediment yield is submitted.

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I. INTRODUCTION

Sediment production from roadways poses a significant pollution problem in forest lands. A roadway that is properly designed, however, can effectively reduce sediment production. Comprehensive design methods are needed to account for variability in temporal and spatial distributions of the principal components of the roadway; the cut and fill slopes, road surfaces, and ditches and culverts. Material used, gradients of the components, changes in precipitation and water runoff, and the degree of ground cover protection may need special consideration. One approach for estimating water and sediment yield uses regression models derived from observed data. Unfortunately, this approach assumes invariance in time and space which is frequently invalid considering the dynamic nature of the environment. Physical process simulation models provide a significant improvement on regression models and other simulation models since they account for variations in time and space, and their associated parameters have physical significance.

Simons et al. (1976) developed a procedural guide for estimating road sediment yield utilizing graphs generated from a physical process simulation model. The following sections present equations used by Simons et al. (1976) in developing those design graphs. The equations represent the important physical processes involved and can be used to develop design aids such as tables or graphs. Included in this report is a computer program that computes and prints design tables.

II. PROCESS EQUATIONS

Complex physical processes govern the common hydraulic and hydrologic phenomena of erosion, water runoff, and sediment yield. Mathematical models can be formulated to simulate these processes and then linked to provide an overall simulation model of the system being studied (Li et al., 1977). For simplicity, the simulation can be approximated by using a series of tables or design graphs (Simons et al., 1976). Each process model remains independent from the others and is used to generate a set of design aids for determining roadway erosion. Linkage between processes is conducted by the user. Separate processes include those related to the roadway components, but are organized into four related groups. These groups are rainfall and runoff from planar surfaces of the roadway and cut and fill slopes; sediment transport from planar surfaces; water and sediment flow in ditches; and water and sediment flow in culverts. Separate processes include rainfall, infiltration, runoff, sediment transport, and sediment supply from rainfall and runoff detachment.

2.1 Assumptions

Assumptions made regarding the physical processes being considered include: 1) rainfall can be represented by a constant duration intensity, 2) runoff from the planar surfaces and the ditch reaches equilibrium almost instantly, and 3) the armoring effect of water or loose soils on the planar surfaces is negligible. These assumptions generally yield a conservative estimate.

2.2 Interception Losses

A certain volume of rainfall is intercepted and stored by canopy and ground cover. In the simplified roadway erosion model it is

assumed the rainfall volume intercepted by vegetation will be

$$V_i = C_c V_c + C_g V_g \quad (1)$$

where V_i is the total intercepted volume in depth, C_c is the canopy cover density, V_c is the potential volume of canopy cover interception, C_g is the ground cover density, and V_g is the potential volume of ground cover interception.

The length of rainfall time needed to satisfy interception losses is found by dividing V_i by the rainfall intensity, i. The interception loss time is then subtracted from the total storm duration to give the length of time of effective rainfall, or

$$D_e = D_t - V_i/i \quad (2)$$

where D_e is the effective rainfall duration and D_t is the total storm duration. Although interception losses are continuous over the storm period it is assumed that losses occur at the storm initiation (Figure 1). In the roadway erosion tabulation procedure, only the effective time period is considered in computations. Determination of interception losses is left to the user.

2.3 Infiltration Losses

The next rainfall loss to be considered are losses from the soil infiltration processes. These processes determine the volume of water that is available for runoff from the planar surface. Time to ponding or the determination of when runoff begins, and the volume of infiltrated water are the most important infiltration characteristics. Under a constant rainfall with steady soil parameters, time of ponding can be determined as (Mein and Larson, 1971).

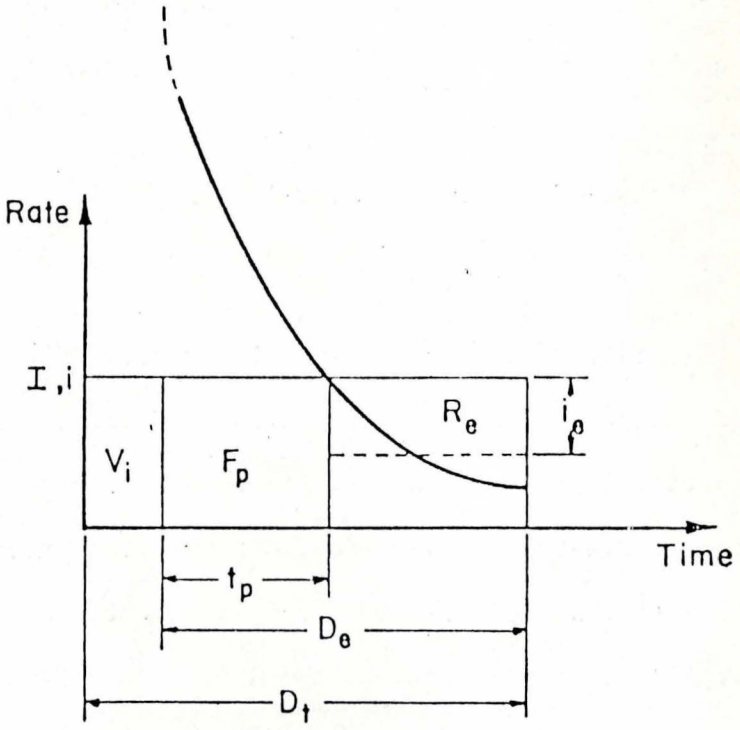

Figure 1. Definition sketch for hydrologic processes.

$$t_p = \frac{\alpha}{i(\frac{i}{\beta} - 1)} \tag{3}$$

where t_p is the time to ponding since the beginning of effective rainfall, α is the soil parameter which is $\phi(S_w - S_i)\psi_{ave}$, ϕ is soil porosity, S_w is the degree of saturation in the wetted zone, S_i is the degree of saturation at the antecedent moisture condition, ψ_{ave} is the average capillary suction head, and β is the hydraulic conductivity in the wetted zone in length per time units which is approximately one-half of the saturated hydraulic conductivity. If $i \leq \beta$, runoff will not occur.

The volume of infiltration can be expressed as (Mein and Larson, 1971)

$$F - \alpha \ell n \ (1 + \frac{F}{\alpha}) = C_1 \tag{4}$$

with

$$C_1 = \beta(D_e - t_p) + F_p - \alpha \ell n \ (1 + \frac{F_p}{\alpha}) \tag{5}$$

and

$$F_p = it_p \tag{6}$$

where F is the total accumulated infiltration in length units at D_t, and F_p is the accumulated infiltration prior to ponding.

Equation 4 is a nonlinear implicit equation for which the following approximate solution can be made (Li et al., 1976):

$$F_1 \simeq \frac{1}{2} \left[C_1 + \sqrt{C_1(C_1 + 8\alpha)}\ \right] \tag{7}$$

where F_1 is the first approximation of F. Because the error on this approximation could range up to eight percent, unacceptable results may be obtained when the amount of rainfall excess is small. Another

approximation can be utilized to yield a better approximation as (Li et al., 1976)

$$F_2 = \alpha \left[\left(1 + \frac{F_1}{\alpha}\right) \sqrt{\left(\frac{F_1}{\alpha}\right)^2 + 2\left[\frac{C_1}{\alpha} - \frac{F_1}{\alpha} + \ell n\left(1 + \frac{F_1}{\alpha}\right)\right]} - \left(\frac{F_1}{\alpha}\right)^2 \right] \quad (8)$$

2.4 Runoff Determination

Once the infiltration volume is determined, the average rainfall excess rate can be determined. The rainfall excess rate can be calculated by

$$i_e = i - \frac{F_2 - F_p}{D_e - t_p} \quad (9)$$

where i_e is the rainfall excess rate.

2.5 Sediment Transport Capacity

When the runoff rate, q, is known, the sediment transport capacity rate on the planar surfaces can be calculated. This is accomplished after determining of several intermediate steps. First, overall flow resistance is assumed as

$$K_g = K_\ell + (K_h - K_\ell)\, C_g^2 \quad (10)$$

where K_g is the parameter describing overall flow resistance associated with cover effects, K_ℓ is the parameter describing minimum resistance for the area ($C_g = 0$), K_h is the parameter describing maximum resistance for the area ($C_g = 1.0$), and C_g is the ground cover in decimal fraction of area covered. An increase in C_g produces a rapid increase in K_g as seen in Figure 2.

Both q and K_g are then used to find the average flow depth as

$$y = \left(\frac{qK_g\nu}{8gS}\right)^{1/3} \quad (11)$$

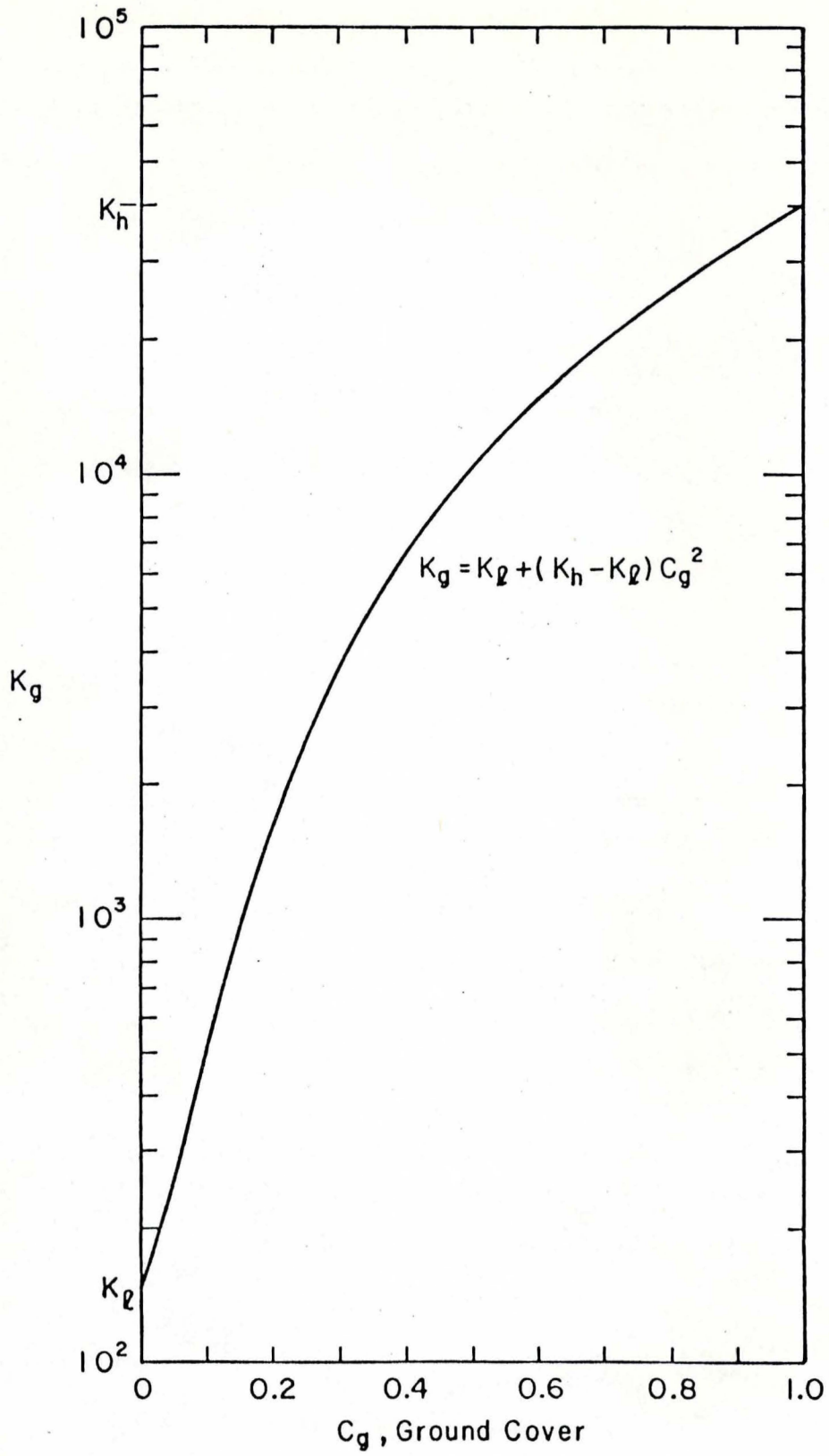

Figure 2. Assumed variation of overall resistance with ground cover.

where y is the flow depth, ν is the kinematic viscosity of water, g is the acceleration of gravity, and S is the slope of the planar surface. The mean flow velocity, V, is then

$$V = \frac{q}{y} \qquad (12)$$

Flow parameters calculated above are used to determine the sediment transport capacity. The procedure for determining the sediment transport capacity given by Simons et al. (1975) is used in this report.

The first sediment transport parameter that should be determined is the tractive force or boundary shear stress. The effective boundary shear stress acting on the sediment grain can be determined by

$$\tau = \frac{1}{8} f\rho V^2 = \frac{1}{8} \frac{K_o}{q} \nu\rho V^2 \qquad (13)$$

where τ is the effective boundary shear stress, f is the Darcy-Weisbach friction factor for grain resistance only, ρ is the density of water and K_o is the parameter describing grain resistance only.

The boundary shear stress considering total resistance (form and grain resistance) is

$$\tau' = \gamma y S \qquad (14)$$

where γ is the unit weight of water. Generally, τ' is much larger than τ. The shear velocity is

$$U_* = \sqrt{\frac{\tau'}{\rho}} \qquad (15)$$

where U_* is the shear velocity.

The transport rate, q_t, is composed of the bed load transport rate, q_b, and the suspended load transport rate, q_s, or

$$q_t = q_b + q_s \qquad (16)$$

The bed load transport rate in weight per time per unit width can be calculated using the Meyer-Peter, Müller formulation (USBR, 1960) as

$$q_b = \frac{12.85}{\sqrt{\rho}} (\tau - \tau_c)^{1.5} \tag{17}$$

where τ_c is the critical shear force for the given particle size. The critical shear force for particle movement is determined from the Shields criteria of

$$\tau_c = \delta\gamma(S_s - 1)\, d_s \tag{18}$$

where δ is a parameter depending on flow conditions, S_s is the specific gravity of the sediment, and d_s is the sediment size in question. The value of S_s usually ranges from 2.60 to 2.70, but δ is dependent on flow conditions and should be adjusted to actual field situations. If τ_c is greater than τ, there is no sediment movement. The suspended load is determined using the Einstein method (Simons et al., 1977) or as

$$q_s = C_a U_* a \frac{E^{(w-1)}}{(1-E)^w} [(\frac{V}{U_*} + 2.5)\, J_1 + 2.5 J_2] \tag{19}$$

where C_a is the sediment concentration at distance a above the land surface, and E, A, a, J_1, and J_2 are given below.

The concentration term is related to the bed load transport as

$$q_b = 11.6\, C_a U_* a \tag{20}$$

Distance a is assumed to be

$$a = 2d_s \tag{21}$$

The dimensionless parameter, E, relates the flow depth to the sediment size as

$$E = \frac{a}{y} \tag{22}$$

The dimensionless parameter, w, is defined as a function of the settling velocity of sediment and the shear velocity or

$$w = \frac{V_s}{\kappa U_*} \tag{23}$$

where V_s is the settling velocity of the sediment and κ is von Karman's number taken as 0.40.

Settling velocities, in feet per second, are a function of particle size and water properties and can be formulated (ASCE, 1975) as

$$V_s = \frac{2.9517\ d_s^2}{\nu} \quad \text{when} \quad d_s < 0.0002 \text{ feet} \tag{24}$$

or

$$V_s = \frac{(36.064\ d_s^3 + 36\nu^2)^{1/2} - 6\nu}{d_s} \quad \text{when} \quad d_s \geq 0.0002 \text{ feet}$$

The terms J_1 and J_2 are integrals resulting from integration of the equation describing the vertical concentration of sediment in the flow. The first integral J_1 is given as

$$J_1 = \int_E^1 \left(\frac{1-\sigma}{\sigma}\right)^w d\sigma \tag{25}$$

where σ is a dimensionless relative position value,

$$\sigma = \frac{\varepsilon}{y} \tag{26}$$

and ε is the distance above the land surface in the flow. The other integral is similar and is given as

$$J_2 = \int_E^1 \ln\sigma\left(\frac{1-\sigma}{\sigma}\right)^w d\sigma \qquad (27)$$

These two integrals can be evaluated by successive integrations of a power series expansion given by Li (1974).

Rearranging Equation 20 and substituting it into Equation 19 gives a simpler form or

$$q_s = \frac{q_b}{11.6} \frac{E^{(w-1)}}{(1-E)^w} \left[\left(\frac{V}{U_*} + 2.5\right) J_1 + 2.5\, J_2\right] \qquad (28)$$

The potential transport rate in height per second per foot of width is then given by Equation 16.

2.6 Determination of Sediment Supply

Potential sediment transport represents the capacity of the system. Supply of sediment comes from two mechanisms: detachment by raindrop splash and detachment by overland flow. Raindrop splash detachment can be formulated as a simple power function of the rainfall intensity (Meyer, 1971) as

$$D = ai^2 \qquad (29)$$

where D is the rate of soil detachment by raindrop splash and a is an empirically determined constant describing soil erodibility.

2.7 Ditch Processes

The processes described above, although indicated for the planar surfaces, also takes place in other roadway components. In ditch flow, however, sediment supply is assumed to be derived from the ditch bottom and sides, and inflows from the planar surfaces. Raindrop splash detachment is neglected because water depth in the ditch provides sufficient protection.

Again, water discharge determines the sediment transport capacity of the system. In the ditch flow, a discharge rate in units of cubic feet per second are used rather than cubic feet per second per foot of width for the planar surface flow. Hydraulic parameters are computed from the assumed discharge in the ditch and ditch geometry. The cross-sectional flow area, A, can be shown using the kinematic wave approximation to be a power function of the discharge, Q, in the ditch as

$$A = \alpha_1 Q^{\beta_1} \tag{30}$$

where α_1 and β_1 can be derived from geometric and flow conditions. For a ditch with a triangular cross-section of equal side slopes of Z (horizontal to vertical), the α_1 and β_1 become

$$\alpha_1 = \left[\frac{K_g (Z + \frac{1}{Z})}{2gS_o} \nu \right]^{1/2} \tag{31}$$

and

$$\beta_1 = 0.5 \tag{32}$$

where K_g is the overall friction factor for the ditch and S_o is the slope of the ditch channel. The depth of flow, y, is given as

$$y = (\frac{A}{Z})^{1/2} \tag{33}$$

and the wetted perimeter P is then

$$p = 2y \sqrt{1 + Z^2} \tag{34}$$

Hydraulic radius, R, is then

$$R = \frac{A}{p} \tag{35}$$

and the mean velocity, V, is

$$V = \frac{Q}{A} \tag{36}$$

These parameters can then be used to determine the tractive force on the ditch as

$$\tau = \frac{1}{8} f\rho V^2 = \frac{1}{8} \frac{K_o \rho \nu}{R} V \tag{37}$$

Other computations for sediment transport parameters in a ditch are similar to those previously presented except R replaces y because the assumption that y approximates R is no longer valid. The sediment supply rate from contributing slopes and road surfaces can then be compared with the ditch sediment carrying capacity to determine if the ditch will aggrade or degrade under various flow conditions.

2.8 Culvert Processes

The culvert model is used to determine if the culvert is large enough to convey both water and sediment without causing a backwater in the ditch, or filling of the culvert with sediment. Manning's equation is used to determine the maximum water discharge the circular culvert is capable of conveying or

$$Q_{max} = \frac{1.486\pi}{n} \frac{D^{8/3}}{10.08} S^{1/2} \tag{38}$$

where Q_{max} is the maximum discharge the culvert can convey, in cubic feet per second, π is 3.14116, n is Manning's coefficient for the culvert, D is the culvert diameter in feet, and S is the slope of the culvert. If the expected incoming Q from the ditch is greater than Q_{max}, a backwater will develop with possible over-road flooding.

Development of a sediment transport equation for an enclosed culvert is difficult because of complicated flow conditions. The equation developed by Graf and Acaroglu (1968) is used since it was developed from a data base that included a large range of pipe flow and open channel conditions.

The equation used is

$$Q_{tmax} = 21.44\ d_s^{-1.02}\ S^{2.52}\ R^{1.52} A \qquad (39)$$

where Q_{tmax} is the maximum sediment discharge rate, in volume per time, that can be conveyed by the conduit. The hydraulic radius, R, is A/P, A is $\frac{\pi D^2}{4}$, and P is πD. If Q_{tmax} is less than the incoming sediment discharge rate from the ditch, the culvert begins to fill with sediment restricting further water flow.

Use of physical process formulations allows improvement or alteration of each process component without changing other components. In this manner each component can be changed or upgraded to meet the needs of the study.

2.9 Computer Program

The above process equations have been programmed in Fortran IV language for the Colorado State University CDC CYBER 171 and 172 computers. This program, ROSETA (Road Sediment Tabulations), is used to develop design tables for various road components. A listing of ROSETA is given in Appendix A. Use of ROSETTA is illustrated in Appendix B.

III. SUMMARY

This report has presented equations that can be used to generate design values to assess sediment yield from forest roadways. These equations, based on physical processes, provide a realistic alternative to existing regression type equations, particularly when assessing impacts resulting from natural or man-caused alterations.

The governing physical processes are similar from region to region, however, the parameters are different. This report will facilitate the development of regional road sediment yield procedural guide by utilizing correct ranges of input data and parameters.

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APPENDIX A

This appendix includes a list of primary variables and a program listing for ROSETA.

FORTRAN Label of Primary Variables	Primary Variables for Program ROSETA Definition
AIN	Parameter in Green-Ampt infiltration function
ALP	Parameter in area-discharge relation
AR	Particle size-flow depth ratio for Einstein's equation
BET	Parameter in area-discharge relation
AREA	Flow Area
BIN	Parameter in Green-Ampt infiltration function
BMV	Coefficient for Einstein's equation
COEMAN	Manning's n value
CROSUF	Grain resistance flow friction factor
CSLSUF	Overall flow friction factor
DCOEF	Coefficient for raindrop splash detachment
DEPTH	Depth of flow
DCG	Ditch cover density
DFL1	Lower value of overall flow resistance parameter for the ditch
DFL2	Upper value of overall flow resistance parameter for the ditch
DISCQ	Water carrying capacity for culvert
DISCS	Sediment carrying capacity for culvert
DIA	Array of culvert diameters
DMB	Sediment size
DMBIN	Vector of sediment sizes

FORTRAN Label of Primary Variables	Primary Variables for Program ROSETA Definition
DPOW	Power of raindrop splash detachment equation
DQ1	Vector of detached soil volumes
DT	Rainfall duration base value
DTHOLD	Effective rainfall duration value
DUREXS	Duration of runoff
DV	Detachment volume, in cubic feet, from raindrop splash
EXR	Rainfall excess rate, inches/hour
FJ	Integral in Einstein's equation
FRA	Infiltration rate
FVB	Particle fall velocity
GC	Ground cover fraction
GCIN	Vector of ground cover density
HYCO	Hydraulic conductivity in wetted zone
HYRAD	Hydraulic radius
NAMESL	Soil name
NDIA	Number of culvert diameters
NDMB	Number of sediment sizes
NGC	Number of ground cover densities
NQ	Number of water discharges
NRAIN	Number of rainfall intensities
NCLCL	Number of culvert gradients
NSLOPE	Number of road gradients
NSLPC	Number of cut and fill slope gradients
NSOIL	Number of soil types
OFL1	Lower value of overall flow resistance parameter for cut and fill slopes

FORTRAN Label of Primary Variables	Primary Variables for Program ROSETA Definition
OFL2	Upper value of overall flow resistance parameter for cut and fill slopes
POROS	Porosity of soil
POTH	Average soil capillary suction pressure in wetted zone
Q	Discharge rate
QIN	Array of water discharges
RA	Rainfall intensity
RAIN	Vector of rainfall intensities
RFL1	Lower value of overall flow resistance factor for road surface
RFL2	Upper value of overall flow resistance factor for road surface
SEDQ	Bed material and total load discharge rate
SI	Soil saturation at antecendent moisture content
SJ	Integral for Einstein's equation
SLOPE	Road gradient
SLPC	Cut and fill slope gradient
SLPCL	Culvert gradient
SS	Specific gravity of sediment
SUSP	Suspended sediment discharge rate
SV	Shear velocity
TAO	Effective boundary shear stress
TAOC	Critical shear stress
TP	Time to ponding
VISCO	Kinematic viscosity of water

FORTRAN Label of Primary Variables	Primary Variables for Program ROSETA Definition
VMEAN	Mean velocity of flow
WEPER	Wetted perimeter
Z	Horizontal to vertical ditch side slope ratio
ZR	Fall velocity-shear velocity ratio for Einstein's equation

Program Listing for ROSETA

```
      PROGRAM ROSETA(INPUT,OUTPUT)
C       THIS PROGRAM IS DESIGNED TO OUTPUT TABLES
C       RELATED TO WATER AND SEDIMENT DISCHARGE FOR THE
C       COMPONENTS OF A ROADWAY PRISM, INCLUDING INTERACTIONS
C       BETWEEN RAINFALL AND SOIL, SEDIMENT DISCHARGE
C       FOR CUT AND FILL SLOPES AND THE ROAD SURFACE,
C       SEDIMENT DISCHARGE RATES FOR THE DITCH, AND
C       CARRYING CAPACITIES FOR THE CULVERT.
C       THIS MAIN PROGRAM COORDINATES ALL OF THE PRIMARY
C       SUBROUTINES FOR DETERMINING AND PRINTING THE TABLES
      COMMON/VAR1/NSLOPE,NDMB,NGC,NQ,NRAIN,NSOIL,NSLPC,NDIA,NSLCL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR3/DT,DTE(30),DTHOLD,TP,TPP(30),EXRT(30),DUREXS
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
      COMMON/VAR6/GCIN(10),OFL1,OFL2,RFL1,RFL2,CROSUF,VISCO
      COMMON/VAR7/Z,COFMAN,DIA(10),DCG,DFL1,DFL2
C       READ IN DATA WITH SUBROUTINE DATA
      CALL DATA
      DO 500 I=1,NSOIL
      SS1=SS(I)
      PRINT 99
   99 FORMAT(1H1)
C       DETERMINE RAINFALL RELATED PROCESSES WITH SUBROUTINE RAINEQ
      CALL RAINEQ(I)
C       DETERMINE SEDIMENT DISCHARGE FOR THE ROAD WAY
C       AND THE CUT AND FILL SLOPES WITH SUBROUTINE SLOPES
      CALL SLOPES(1)
      CALL SLOPES(2)
C       DETERMINE DITCH TRANSPORT WITH SUBROUTINE DITCH
      CALL DITCH
C       DETERMINE CULVERT CARRYING CAPACITIES WITH SUBROUTINE CULVT
      CALL CULVT
  500 CONTINUE
       STOP
       END
```

```
      SUBROUTINE DATA
C     THIS SUBROUTINE IS USED TO READ IN THE NECESSARY DATA
      COMMON/VAR1/NSLOPE,NDMB,NGC,NQ,NRAIN,NSOIL,NSLPC,NDIA,NSLCL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR3/DT,DTE(30),DTHOLD,TP,TPP(30),EXRT(30),DUREXS
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
      COMMON/VAR6/GCIN(10),OFL1,OFL2,RFL1,RFL2,CROSUF,VISCO
      COMMON/VAR7/Z,COEMAN,DIA(10),DCG,DFL1,DFL2
C     READ DIMENSIONS OF PROBLEM
      READ 100,NSOIL,NRAIN,NQ,NGC,NDIA,NDMB
      READ 100,NSLPC,NSLOPE,NSLCL
C     READ RAINFALL AND FLOW INPUTS
      READ 120,(RAIN(I),I=1,NRAIN)
C     READ TIMING VALUE
      READ 120,DT
      READ 120,(QIN(I),I=1,NQ)
C     READ SLOPE VALUES IN PERCENT
      READ 120,(SLPC(I),I=1,NSLPC)
      READ 120,(SLOPE(I),I=1,NSLOPE)
      READ 120,(SLPCL(I),I=1,NSLCL)
C     READ SOIL PARAMETERS AND PARTICLE SIZES
      READ 130,(((NAMESL(I,J),J=1,20),POTH(I),HYCO(I),SI(I),POROS(I),
     1DCOEF(I),DPOW(I),SS(I)),I=1,NSOIL)
      READ 120,(DMBIN(I),I=1,NDMB)
C     READ VEGETATION PARAMETERS
      READ 120,(GCIN(I),I=1,NGC)
      READ 120,OFL1,OFL2,RFL1,RFL2,DFL1,DFL2
C     READ DITCH AND CULVERT CHARACTERISTICS
      READ 120,Z,DCG,COEMAN
      READ 120,(DIA(I),I=1,NDIA)
C     READ FLOW CHARACTERISTICS
      READ 120,CROSUF,VISCO
C     CHANGE UNITS AND SET CONSTANTS
      WIDTH=1.0
      SLENG=1.0
      DT=DT/60.
      VISCO=VISCO/100000.
  100 FORMAT(8I10)
  120 FORMAT(8F10.2)
  130 FORMAT(20A4/7F10.2,10X)
      RETURN
      END
```

```
      SUBROUTINE RAINEQ(IP)
C       THIS SUBROUTINE DETERMINES RAINFALL EXCESS RATE,
C       TIME TO PONDING, AND SOIL DETACHMENT VOLUME RATES
C       FOR DIFFERENT RAINFALL INTENSITIES
      COMMON/VAR1/NSLOPE,NDMB,NGC,NQ,NRAIN,NSOIL,NSLPC,NDIA,NSLCL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR3/DT,DTE(30),DTHOLD,TP,TPP(30),EXRT(30),DUREXS
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SSI
      DIMENSION LTPPRT(3)
C     SET PRINTED OUTPUT STATEMENT
      LTPPRT(1)=10H BEYOND RA
      LTPPRT(2)=10HIN DURATIO
      LTPPRT(3)=1HN
C       DETERMINE RAINFALL TABLES FOR ONE-HALF DT, ALL OF DT,
C       AND TWICE DT.
      DO 500 K=1,3
      DTP=K-2
      DTHOLD=DT*(2.**DTP)
      DO 520 J=1,NRAIN
      RA=RAIN(J)
C       DETERMINE INFILTRATION LOSSES WITH SUBROUTINE INFIL
      CALL INFIL(IP)
C       CALCULATE EXCESS RUNOFF RATE
      EXR(J)=RA-FRA
C       CALCULATE EXCESS RUNOFF PERIOD
      EXRT(J)=DUREXS
C       DETERMINE RAINFALL DETACHMENT WITH SUBROUTINE DETACH
      CALL DETACH(IP)
      DQ1(J)=DV*DTHOLD*12./DT
C       CALCULATE TIME TO PONDING
      TPP(J)=DTHOLD-EXRT(J)
  520 CONTINUE
C       PRINT TABLE TITLES
      PRINT 99
   99 FORMAT(1H1)
      PRINT 29,K,(NAMESL(IP,KK),KK=1,20),DTHOLD
   29 FORMAT(15X,*TABLE 1-*I1* RAINFALL EXCESS, TIME TO PONDING AND*/
     125X*SOIL DETACHMENT VOLUME FOR SOIL*/25X,20A4/25X
     2*EFFECTIVE RAINFALL DURATION=*F5.2* HOUR*/25X
     3*INTENSITY AND EXCESS IN INCHES PER HOUR*/25X*DETACHMENT VOLUME IN
     4 INCHES OF DEPTH*/26X*PER SQUARE FOOT FOR THE */26X*RAINFALL DURAT
     5ION*///)
      PRINT 30
   30 FORMAT(11X*RAINFALL INTENSITY*3X*RAINFALL EXCESS*3X
     1*TIME TO PONDING,HOURS*3X*SOIL DETACHMENT VOLUME*/)
      DO 510 I1=1,NRAIN
      IF(TPP(I1).LT.DTHOLD) PRINT 31,RAIN(I1),EXR(I1),TPP(I1),DQ1(I1)
   31 FORMAT(17X,F6.3,14X,F6.3,16X,F6.3,18X,F7.3/)
      IF(TPP(I1).GE.DTHOLD) PRINT 32,RAIN(I1),EXR(I1),LTPPRT,DQ1(I1)
   32 FORMAT(17X,F6.3,14X,F6.3,7X,A10,A10,A1,12X,F7.3/)
  510 CONTINUE
      PRINT 33
   33 FORMAT(2X////)
  500 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INFIL(K)
C       THIS SUBROUTINE DETERMINES THE INFILTRATION RATE,
C       THE TIME OF PONDING, AND THE PERIOD OF RUNOFF
C       ALL OF THESE COMPUTATIONS ARE DONE BY AN ANALYTICAL FORMULATION
C       OF THE GREEN-AMPT INFILTRATION FUNCTION
      COMMON/VAR3/DT,DTE(30),DTHOLD,TP,TPP(30),EXRT(30),DUREXS
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
C       CALCULATE PARAMETERS FOR THE GREEN-AMPT FUNCTION
      AIN=POROS(K)*(1.-SI(K))*POTH(K)
      BIN=HYCO(K)
      IF(RA.LE.BIN) GO TO 100
C       CALCULATE TIME TO PONDING FROM BEGINNING OF INFILTRATION
      TP=AIN/((RA*RA/BIN)-RA)
      IF(TP.GE.DTHOLD) GO TO 100
C       CALCULATE FIRST INFILTRATION APPROXIMATION
      FTP=TP*RA
      DUREXS=DTHOLD-TP
      CHOLD=(1.+FTP/AIN)
      C1=BIN*DUREXS+FTP-AIN*ALOG(CHOLD)
      CHOLD=C1*(C1+8.0*AIN)
      FTOT=0.5*(C1+SQRT(CHOLD))
C       CALCULATE SECOND INFILTRATION APPROXIMATION
      F1=FTOT/AIN
      CHOLD=F1*F1+2.0*((C1/AIN)-F1+ALOG(1.0+F1))
      CHOLD=SQRT(CHOLD)
      FTOT=AIN*((1.0+F1)*CHOLD-F1*F1)
      FTOT=FTOT-FTP
      IF(FTOT.LE.0.0) FTOT=0.0
      FRA=FTOT/DUREXS
      IF(FRA.GE.RA) GO TO 100
      RETURN
  100 CONTINUE
      DUREXS=0.0
      FRA=RA
      RETURN
      END
```

```
      SUBROUTINE SLOPES(ITYPE)
C      THIS SUBROUTINE DETERMINES SEDIMENT DISCHARGE GIVEN
C      CERTAIN INPUT CONDITIONS AND PRINTS THE RESULTS.
      COMMON/VAR1/NSLOPE,NDMB,NGC,NQ,NRAIN,NSOIL,NSLPC,NDIA,NSLCL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
      COMMON/VAR6/GCIN(10),OFL1,OFL2,RFL1,RFL2,CROSUF,VISCO
      DIMENSION SEDPRT(30),GCPR(10)
      DO 500 J1=1,NDMB
      DMBP=DMBIN(J1)
      DMB=DMBIN(J1)/304.8
      NSLP=NSLOPE
      IF(ITYPE.EQ.2) NSLP=NSLPC
      DO 510 J2=1,NSLP
      SLP=SLOPE(J2)
      IF(ITYPE.EQ.2) SLP=SLPC(J2)
      IF(ITYPE.EQ.2) SLPT=1./SLP
      IF(SLP.GT.0.25) SLP=SIN(ATAN(SLP))
      A1=RFL1
      A2=RFL2
      IF(ITYPE.EQ.2) A1=OFL1
      IF(ITYPE.EQ.2) A2=OFL2
      JP=J1+1
      IF(ITYPE.EQ.2) JP=J1+1+NDMB
      PRINT 99
   99 FORMAT(1H1)
C      PRINT THE TABLE TITLES
      IF(ITYPE.EQ.1) PRINT 39,JP,J2,DMBP,SLP
      IF (ITYPE.EQ.2) PRINT 40,JP,J2,DMBP,SLPT
   39 FORMAT(2X////15X*TABLE*I2*-*I1* SEDIMENT TRANSPORT RATE FOR SEDIME
     1NT SIZE=*F6.3*MM*/25X*ON ROAD SLOPE OF*F5.3)
   40 FORMAT(2X////15X*TABLE*I2*-*I1* SEDIMENT TRANSPORT RATE FOR SEDIME
     1NT SIZE=*F6.3*MM*/25X*ON CUT OR FILL SLOPE OF *F4.1,1X*HORIZONTAL
     3*/25X*TO 1 VERTICAL*)
      PRINT 41
   41 FORMAT(25X*GC IS GROUND COVER IN PERCENT*///)
      DO 77 KGC=1,NGC
      GCPR(KGC)=GCIN(KGC)*100.
   77 CONTINUE
      PRINT 42,(GCPR(KGC),KGC=1,NGC)
   42 FORMAT(49X*QS(LBS/SEC/FT)*/12X*Q(CFS/FT)*6X*GC=*3X,F5.1,5(5X,F5.1)
     1)
      DO 520 J3=1,NQ
C      SET DISCHARGE FROM INPUT DATA
      Q=QIN(J3)
      DO 530 KGC=1,NGC
      GC=GCIN(KGC)
      TAOC=0.047*62.4*(SS1-1.)*DMB
      CSLSUF=A1+(A2-A1)*GC*GC
      DEPTH=(Q*CSLSUF*VISCO/(257.6*SLP))**(1./3.)
      VMEAN=Q/DEPTH
      TAO=0.24225*CROSUF*VISCO*Q/(DEPTH**2.)
      IF(TAO.GT.TAOC) GO TO 400
      SUSP=0.0
      SEDQ=0.0
      GO TO 420
C      CALCULATE BED LOAD DISCHARGE
```

```
SUBROUTINE  SLOPES

          400 SEDQ=(12.85/1.392)*(TAO-TAOC)**(1.5)
              AR=2.*DMB/DEPTH
              IF(AR.GT.0.9) GO TO 410
              SV=SQRT(62.4*DEPTH*SLP/1.938)
              FVB=(SQRT(36.064*DMB**3+36.*VISCO**2)-6.*VISCO)/DMB
              IF(DMB.LE.0.0002) FVB=2.9517*DMB**2/VISCO
              ZR=FVB/(0.4*SV)
              BMV=2.5+VMEAN/SV
              CALL POWER (ZR,AR,FJ,SJ,1.0E-2)
              P=AR**(ZR-1.)/(11.6*(1.-AR)**ZR)
        C      CALCULATE SUSPENDED LOAD DISCHARGE
              SUSP=P*(BMV*FJ+2.5*SJ)
              IF(SUSP.GE.0.0) GO TO 420
          410 SUSP=0.0
          420 CONTINUE
        C      CALCULATE TOTAL DISCHARGE
              SEDQ=(1.+SUSP)*SEDQ
              SEDPRT(KGC)=SEDQ
          530 CONTINUE
              PRINT 43,QIN(J3),(SEDPRT(I),I=1,NGC)
           43 FORMAT(14X,F5.3,13X,F7.3,4X,F6.3,4(4X,F6.3))
          520 CONTINUE
          510 CONTINUE
          500 CONTINUE
               RETURN
               END
```

```
      SUBROUTINE POWER (Z,A,XJ1,XJ2,CONV)
C      THIS SUBROUTINE EVALUATES THE J1 AND THE J2 INTEGRALS
C      USED IN THE SUSPENDED SEDIMENT DISCHARGE CALCULATION
C     NOTATIONS
C     XJ1= VALUE OF J1 INTEGRAL
C     XJ2= VALUE OF J2 INTEGRAL
C     N = ORDER OF APPROXIMATION + 1
C     CONV = CONVERGENCE CRITERION
      N=1
      XJ1=0.
      XJ2=0.
      ALG=ALOG(A)
      C=1.
      D=-Z
      E=D+1.
      FN=1.
      AEX=A**E
      GO TO 1
    2 N=N+1
      C=C*D/FN
      D=E
      E=D+1.
      FN=FLOAT(N)
      AEX=A**E
    1 IF(ABS(E) .LE. 0.001) GO TO 3
      XJ1=XJ1+C*(1.-AEX)/E
      XJ2=XJ2+C*((AEX-1.)/E**2-AEX*ALG/E)
      GO TO 4
    3 XJ1=XJ1-C*ALG
      XJ2=XJ2-0.5*C*ALG**2
    4 IF(N .EQ. 1) GO TO 5
      CJ1=ABS(1.-FJ1/XJ1)
      CJ2=ABS(1.-FJ2/XJ2)
      IF(CJ1 .LE. CONV .AND. CJ2 .LE. CONV) RETURN
    5 FJ1=XJ1
      FJ2=XJ2
      GO TO 2
        END
```

```
      SUBROUTINE DETACH(K)
C       THIS SUBROUTINE DETERMINES THE
C       SOIL DETACHMENT RATE FOR THE SELECTED SOIL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR3/DT,DTE(30),DTHOLD,TP,TPP(30),EXRT(30),DUREXS
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
      COMMON/VAR6/GCIN(10),OFL1,OFL2,RFL1,RFL2,CROSUF,VISCO
C       CALCULATE DETACHMNET RATE
      DQ=DCOEF(K)*(RA**DPOW(K))
C       CALCULATE DETACHMENT VOLUME
      DV=DQ*DT*SLENG*WIDTH*(1.-POROS(K))/12.
      RETURN
      END
```

```
      SUBROUTINE DITCH
C       THIS SUBROUTINE DETERMINES THE SEDIMENT TRANSPORT
C       IN A DITCH FOR DIFFERENT CONDITIONS
      COMMON/VAR1/NSLOPE,NDMB,NGC,NQ,NRAIN,NSOIL,NSLPC,NDIA,NSLCL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR4/RAIN(30),RA,EXR(30),QIN(30),FRA,DQ1(30),DV,DQ
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
      COMMON/VAR6/GCIN(10),OFL1,OFL2,RFL1,RFL2,CROSUF,VISCO
      COMMON/VAR7/Z,COEMAN,DIA(10),DCG,DFL1,DFL2
      DIMENSION SEDQT(30)
      CSLSUF=DFL1+(DFL2-DFL1)*DCG*DCG
      DCGP=DCG*100.
      DO 500 ND=1,NDMB
      DMB=DMBIN(ND)/304.8
      DMBPRT=DMBIN(ND)
      DO 510 K=1,NSLOPE
      JP=ND+1+2*NDMB
      SLP=SLOPE(K)
      PRINT 99
   99 FORMAT(1H1)
      PRINT 40,JP,K,DMBPRT,Z,SLP,DCGP
   40 FORMAT(2X///15X*TABLE*I3*-*I2* SEDIMENT DISCHARGE FOR SEDIMENT SIZ
     1E=*F7.4* MM*/27X*IN A DITCH WITH *F4.1* HORIZONTAL ON 1 VERTICAL*/
     227X*SIDE SLOPE AND A LONGITUDINAL SLOPE OF*F6.3/27X*DITCH COVER DE
     3NSITY, PERCENT =*F5.1/)
      PRINT 41
   41 FORMAT(2X/20X*DISCHARGE IN CFS*10X
     1*SEDIMENT DISCHARGE IN LBS/SEC*/)
      DO 530 J=1,NQ
      Q=QIN(J)*10.
      ALP=(CSLSUF*(1.+Z*Z)/Z*VISCO/64.4/SLP)**(1./2.)
      BET=0.5
      AREA=ALP*Q**BET
      DEPTH=SQRT(AREA/Z)
      WEPER=DEPTH*SQRT(1+Z*Z)*2.
      HYRAD=Z/(2.*SQRT(1.+Z*Z))*DEPTH
      VMEAN=Q/AREA
      TAO=0.24225*CROSUF*VMEAN*VMEAN/(Q*HYRAD/(VISCO*AREA))
      TAOC=0.047*62.4*(SS1-1.)*DMB
      IF(TAO.LE.TAOC) GO TO 410
      AR=2.*DMB/HYRAD
      IF(AR.GT.0.9) GO TO 400
      SV=SQRT(62.4*HYRAD*SLP/1.938)
      FVB=(SQRT(36.064*DMB**3+36.*VISCO**2)-6.*VISCO)/DMB
      IF(DMB.LE.0.0002) FVB=2.9517*DMB**2/VISCO
      ZR=FVB/(0.4*SV)
      BMV=2.5+VMEAN/SV
      CALL POWER (ZR,AR,FJ,SJ,1.0E-2)
      P=AR**(ZR-1.)/(11.6*(1.-AR)**ZR)
      SUSP=P*(BMV*FJ+2.5*SJ)
      IF(SUSP.GT.0.0) GO TO 420
  400 SUSP=0.0
      GO TO 420
  410 CONTINUE
      SEDD=0.
      SUSP=0.
      GO TO 430
  420 SEDD=(12.85/1.392)*(TAO-TAOC)**(1.5)

  430 SEDQ=(1.+SUSP)*SEDD
      SEDQ=SEDQ*Z*DEPTH*2.
      SEDQT(J)=SEDQ
  530 CONTINUE
      DO 520 J=1,NQ
      Q=QIN(J)*10.
      PRINT 42,Q,SEDQT(J)
   42 FORMAT(27X,F5.2,27X,F9.4)
  520 CONTINUE
  510 CONTINUE
  500 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CULVT
C       THIS SUBROUTINE DETERMINES THE CARRYING CAPACITY
C       FOR CULVERTS OF DIFFERINT DIAMETERS
      COMMON/VAR1/NSLOPE,NDMB,NGC,NQ,NRAIN,NSOIL,NSLPC,NDIA,NSLCL
      COMMON/VAR2/WIDTH,SLENG,SLOPE(20),SLPC(20),SLPCL(20)
      COMMON/VAR5/POTH(10),HYCO(10),SI(10),POROS(10),DCOEF(10),DPOW(10)
     1,SS(10),DMBIN(10),NAMESL(10,20),SS1
      COMMON/VAR6/GCIN(10),OFL1,OFL2,RFL1,RFL2,CROSUF,VISCO
      COMMON/VAR7/Z,COEMAN,DIA(10),DCG,DFL1,DFL2
      DIMENSION DISCQ(30),DISCS(30)
      DO 500 L=1,NDMB
      DMB=DMBIN(L)/304.8
      DO 510 I=1,NDIA
      DIA1=DIA(I)/12.
      JP=L+1+3*NDMB
      PRINT 99
   99 FORMAT(1H1)
      PRINT 39,JP,I,DIA(I),DMBIN(L)
   39 FORMAT(15X*TABLE*I3*-*I2,2X*WATER AND SEDIMENT CARRYING CAPACITIES
     1*/28X*FOR A CULVERT *F3.0* INCHES IN DIAMETER*/28X*SEDIMENT SIZE=*
     2F7.3* MM*///)
      PRINT 40
   40 FORMAT(25X*SLOPE*10X*Q(CFS)*6X*QS(LBS/SEC)*/)
      DO 520 J=1,NSLCL
      SLOPC=SLPCL(J)
      C1=1.486/COEMAN*3.1416/(4.**(5./3.))*DIA1**(8./3.)
      DISCQ(J)=C1*SLOPC**(0.5)
      CONV=0.6517*DMB**(-1.02)*SLOPC**2.52*DIA1**2.52
      DISCS(J)=DISCQ(J)*CONV*165.36
      PRINT 41,SLOPC,DISCQ(J),DISCS(J)
   41 FORMAT(24X,F6.3,10X,F6.2,4X,F12.2)
  520 CONTINUE
  510 CONTINUE
  500 CONTINUE
      RETURN
      END
```

APPENDIX B

Input Sequence and Sample Input and Output for Program ROSETA

Input Sequence for PROGRAM ROSETA

Card	Columns	Format	Variable Label	Contents
1	1-10	I10	NSOIL	Number of soils considered
	11-20	I10	NRAIN	Number of rainfall intensities considered
	21-30	I10	NQ	Number of discharges
	31-40	I10	NGC	Number of ground cover densities considered
	41-50	I10	NDIA	Number of culvert diameters considered
	51-60	I10	NDMB	Number of sediment sizes considered
2	1-10	I10	NSLPC	Number of cut and fill slope gradients considered
	11-20	I10	NSLOPE	Number of road surface gradients considered
	21-30	I10	NSLCL	Number of culvert gradients considered
3 (can be more than one card)	1-80	8F10.2	RAIN (I)	Array of rainfall intensities up to NRAIN, inches/hr
4	1-10	F10.2	DT	Length of rainfall, minutes Note: Tables of DT, 2DT and 0.5 DT will be printed
5 (can be more than one card)	1-80	8F10.2	QIN (I)	Array of water discharges up to NQ, cfs/ft. Note: QIN is multiplied by 10 for ditch flow computations
6 (can be more than one card)	1-80	8F10.2	SLPC (I)	Array of cut and fill slope gradients, enter as decimal fraction of vertical to horizontal ratio

Card	Columns	Format	Variable Label	Contents
7 (can be more than one card)	1-80	8F10.2	SLOPE (I)	Array of road slope
8	1-80	8F10.2	SLPCL (I)	Array of culvert gradients, enter as decimal fraction of vertical to horizontal ratio
9-10 (can be more than one set of two)	1-80	20A4	NAMESL	User name for soil type considered
	1-10	F10.2	POTH	Average capillary suction
	11-20	11	HYCO	Hydraulic conductivity in the wetted zone, inches/hr
	21-30	11	SI	Soil saturation at antecedent moisture content before rainfall, decimal fraction
	31-40	11	POROS	Porosity of the soil, decimal fraction
	41-50	11	DCOEF	Coefficient on raindrop soil detachment equation
	51-60	11	DPOW	Power on raindrop soil detachment equation
	61-70	11	SS	Specific gravity of soil particles
11 (can be more than one card)	1-80	8F10.2	DMBIN (I)	Array of sediment sizes, millimeters
12	1-80	8F10.2	GCIN (I)	Array of ground cover densities, decimal fraction of area
13	1-10	F10.2	OFLI	Lower value of overall resistance parameter for cut and fill slopes
	11-20	F10.2	OFL2	Upper value of overall resistance parameter for cut and fill slopes

Card	Columns	Format	Variable Label	Contents
	21-30	F10.2	RFL 1	Lower value of overall resistance parameter for road surfaces
	31-40	F10.2	RFL2	Upper value of overall resistance parameter for road surfaces
	41-50	F10.2	DFL1	Lower value of overall resistance parameter for the ditch
	51-60	F10.2	DFL2	Upper value of overall resistance parameter for the ditch
14	1-10	F10.2	Z	Gradient of ditch side slope, ratio of horizontal to vertical
	11-20	F10.2	DCG	Cover density for the ditch, decimal fraction
	21-30	F10.2	COEMAN	Manning's coefficient for the culvert
15 (can be more than one card)	1-80	8F10.2	DIA	Array of Culvert diameters
16	1-10	F10.2	CROSUF	Grain resistance coefficient
	11-20	F10.2	VISCO	Kinematic viscosity of water, ft^2/sec Note: This value is divided by 100,000, so enter correctly

Sample Input and Output for Program ROSETA

Input data used to generate the following output tables is given below:

SAMPLE INPUT:

NSOIL = 1

NRAIN = 18

NQ = 18

NGC = 6

NDIA = 1

NDMB = 1

NSLPC = 1

NSLOPE = 1

NSLCL = 5

RAIN = See Table 1-1, 1-2, or 1-3, Column 1

DT = 30 minutes

QIN = See Table 2-1, Column 1

SLPC = 0.25 (=1/4.0)

SLOPE = 0.05

SLPCL = See Table 5-1, Column 1

NAMESL = Hypothetical Soil Number 1

POTH = 17.68 inches

HYCO = 0.25 inches/hour

SI = 0.57

POROS = 0.44

DCOEF = 0.001

DPOW = 2.0

SS = 2.65

DMBIN = 0.40 mm

GCIN = 0, 0.1, 0.3, 0.5, 0.7, 1.0

OFL1 = 150

OFL2 = 40000

RFL1 = 150

RFL2 = 500

DFL1 = 150

DFL2 = 400

Z = 3.0

DCG = 0.3

COEMAN = 0.025

DIA = 36 inches

CROSUF = 50

VISCO = 1.05 ft^2/sec (Note that this value is divided by 100000 in program)

SAMPLE OUTPUT:

The following tables are computer generated by Program ROSETA using the above input data. Table 1-1 to 1-3 are related to processes of rainfall-soil interactions. The numbers after the dashes correspond to the rainfall duration time, e.g. 1-3 where "3" stands for 1.0 hours, which is twice the input DT value. If the runoff does not occur within the rainfall duration, "beyond rain duration" is printed. For rainfall intensities that produce runoff within the rain duration, the rainfall excess and time to ponding are printed. A soil detachment volume is computed and printed for all rainfall intensities if they are greater than .0005 inch per square foot as displayed in Tables 1-1, 1-2, and 1-3.

Sediment transport rates for road slopes under various ground cover densities are shown in Table 2-1. The number "2" in the table heading refers to the sediment size, and number "1" to the slope. For example, if two sediment sizes are used with two slopes, four tables would be printed as Tables 2-1 and 2-2 for the first sediment size for both slopes, then Tables 3-1 and 3-2 for the second size and the same two slopes. The effects of different ground cover densities can be observed as the cover density increases for the same water discharge.

The table for cut and fill slopes, Table 3-1, is similar to Table 2-1 in the numbering system for sediment sizes and slopes. Both tables present information on the potential sediment transport related to slope, water discharge, sediment size, and ground cover. The overland flow resistance factors used in developing Table 3-1 are higher because of the higher resistance provided by vegetative slope covers.

Table 4-1 presents sediment discharge rates for a ditch with a triangular cross section. The numbering system is similar to the previous two tables for sediment sizes and slopes. Water discharges are selected as ten times the discharges in the previous two tables. This was done for convenience but also covers a wide range of flow conditions. A ditch cover factor is included for ditches with natural or artificial linings.

Water and sediment carrying capacities for various culvert gradients and diameters are presented in Table 5-1. In this Table, "5" stands for the sediment size and, therefore, increases by 1 as each other size is considered. The "1" stands for the culvert size and changes since more than 1 culvert size is considered.

All of the above tables are repeated for each change in the type of soil. This was done to provide a complete set of tables for each soil

type. These tables can be plotted to serve as continuous discharge aids or used directly with interpolation techniques.

TABLE 1-1 RAINFALL EXCESS, TIME TO PONDING AND SOIL DETACHMENT VOLUME FOR SOIL HYPOTHETICAL SOIL NUMBER 1
EFFECTIVE RAINFALL DURATION= .25 HOUR
INTENSITY AND EXCESS IN INCHES PER HOUR
DETACHMENT VOLUME IN INCHES OF DEPTH PER SQUARE FOOT FOR THE RAINFALL DURATION

RAINFALL INTENSITY	RAINFALL EXCESS	TIME TO PONDING,HOURS	SOIL DETACHMENT VOLUME
.010	0.000	BEYOND RAIN DURATION	.000
.025	0.000	BEYOND RAIN DURATION	.000
.050	0.000	BEYOND RAIN DURATION	.000
.075	0.000	BEYOND RAIN DURATION	.000
.100	0.000	BEYOND RAIN DURATION	.000
.250	0.000	BEYOND RAIN DURATION	.000
.500	0.000	BEYOND RAIN DURATION	.000
.750	0.000	BEYOND RAIN DURATION	.000
1.000	0.000	BEYOND RAIN DURATION	.000
2.000	.039	.239	.001
3.000	.919	.101	.001
4.000	1.812	.056	.002
5.000	2.732	.035	.003
7.000	4.623	.018	.007
9.000	6.554	.011	.011
11.000	8.505	.007	.017
13.000	10.470	.005	.024
15.000	12.443	.004	.031

TABLE 1-2 RAINFALL EXCESS, TIME TO PONDING AND SOIL DETACHMENT VOLUME FOR SOIL HYPOTHETICAL SOIL NUMBER 1
EFFECTIVE RAINFALL DURATION= .50 HOUR
INTENSITY AND EXCESS IN INCHES PER HOUR
DETACHMENT VOLUME IN INCHES OF DEPTH PER SQUARE FOOT FOR THE RAINFALL DURATION

RAINFALL INTENSITY	RAINFALL EXCESS	TIME TO PONDING,HOURS	SOIL DETACHMENT VOLUME
.010	0.000	BEYOND RAIN DURATION	.000
.025	0.000	BEYOND RAIN DURATION	.000
.050	0.000	BEYOND RAIN DURATION	.000
.075	0.000	BEYOND RAIN DURATION	.000
.100	0.000	BEYOND RAIN DURATION	.000
.250	0.000	BEYOND RAIN DURATION	.000
.500	0.000	BEYOND RAIN DURATION	.000
.750	0.000	BEYOND RAIN DURATION	.000
1.000	0.000	BEYOND RAIN DURATION	.000
2.000	.502	.239	.001
3.000	1.392	.101	.003
4.000	2.319	.056	.004
5.000	3.269	.035	.007
7.000	5.204	.018	.014
9.000	7.164	.011	.023
11.000	9.138	.007	.034
13.000	11.118	.005	.047
15.000	13.104	.004	.063

TABLE 1-3 RAINFALL EXCESS, TIME TO PONDING AND SOIL DETACHMENT VOLUME FOR SOIL HYPOTHETICAL SOIL NUMBER 1
EFFECTIVE RAINFALL DURATION= 1.00 HOUR
INTENSITY AND EXCESS IN INCHES PER HOUR
DETACHMENT VOLUME IN INCHES OF DEPTH PER SQUARE FOOT FOR THE RAINFALL DURATION

RAINFALL INTENSITY	RAINFALL EXCESS	TIME TO PONDING, HOURS	SOIL DETACHMENT VOLUME
.010	0.000	BEYOND RAIN DURATION	.000
.025	0.000	BEYOND RAIN DURATION	.000
.050	0.000	BEYOND RAIN DURATION	.000
.075	0.000	BEYOND RAIN DURATION	.000
.100	0.000	BEYOND RAIN DURATION	.000
.250	0.000	BEYOND RAIN DURATION	.000
.500	0.000	BEYOND RAIN DURATION	.000
.750	0.000	BEYOND RAIN DURATION	.000
1.000	0.000	BEYOND RAIN DURATION	.001
2.000	.829	.239	.002
3.000	1.754	.101	.005
4.000	2.708	.056	.009
5.000	3.679	.035	.014
7.000	5.642	.018	.027
9.000	7.620	.011	.045
11.000	9.606	.007	.068
13.000	11.596	.005	.095
15.000	13.588	.004	.126

TABLE 2-1 SEDIMENT TRANSPORT RATE FOR SEDIMENT SIZE= .400MM
ON ROAD SLOPE OF .050
GC IS GROUND COVER IN PERCENT

		QS(LBS/SEC/FT)					
Q(CFS/FT)	GC=	0.0	10.0	30.0	50.0	70.0	100.0
.001		0.000	0.000	0.000	0.000	0.000	0.000
.002		.000	.000	0.000	0.000	0.000	0.000
.004		.001	.001	.000	0.000	0.000	0.000
.006		.002	.002	.001	.000	0.000	0.000
.008		.003	.002	.001	.000	0.000	0.000
.010		.003	.003	.002	.001	.000	0.000
.020		.008	.007	.005	.003	.001	0.000
.030		.012	.011	.008	.005	.002	.000
.035		.014	.013	.010	.006	.003	.000
.040		.016	.015	.012	.007	.003	.001
.045		.018	.018	.013	.008	.004	.001
.050		.020	.020	.015	.009	.005	.001
.060		.025	.024	.018	.011	.006	.002
.070		.029	.028	.021	.013	.008	.002
.080		.033	.032	.025	.016	.009	.003
.090		.038	.036	.028	.018	.010	.004
.100		.042	.041	.032	.020	.012	.004
.200		.092	.089	.070	.046	.028	.013

TABLE 3-1 SEDIMENT TRANSPORT RATE FOR SEDIMENT SIZE= .400MM
ON CUT OR FILL SLOPE OF 4.0 HORIZONTAL
TO 1 VERTICAL
GC IS GROUND COVER IN PERCENT

		QS(LBS/SEC/FT)					
Q(CFS/FT)	GC=	0.0	10.0	30.0	50.0	70.0	100.0
.001		.008	.000	0.000	0.000	0.000	0.000
.002		.014	.001	0.000	0.000	0.000	0.000
.004		.023	.002	0.000	0.000	0.000	0.000
.006		.032	.004	0.000	0.000	0.000	0.000
.008		.040	.005	0.000	0.000	0.000	0.000
.010		.047	.007	0.000	0.000	0.000	0.000
.020		.081	.014	0.000	0.000	0.000	0.000
.030		.115	.020	0.000	0.000	0.000	0.000
.035		.131	.024	0.000	0.000	0.000	0.000
.040		.148	.027	0.000	0.000	0.000	0.000
.045		.165	.031	0.000	0.000	0.000	0.000
.050		.183	.034	.000	0.000	0.000	0.000
.060		.218	.041	.000	0.000	0.000	0.000
.070		.254	.049	.000	0.000	0.000	0.000
.080		.292	.056	.001	0.000	0.000	0.000
.090		.330	.064	.001	0.000	0.000	0.000
.100		.369	.072	.001	0.000	0.000	0.000
.200		.804	.162	.006	0.000	0.000	0.000

TABLE 4- 1 SEDIMENT DISCHARGE FOR SEDIMENT SIZE= .4000 MM
IN A DITCH WITH 3.0 HORIZONTAL ON 1 VERTICAL
SIDE SLOPE AND A LONGITUDINAL SLOPE OF .050
DITCH COVER DENSITY, PERCENT = 30.0

DISCHARGE IN CFS	SEDIMENT DISCHARGE IN LBS/SEC
.01	.0030
.02	.0063
.04	.0132
.06	.0206
.08	.0285
.10	.0366
.20	.0819
.30	.1326
.35	.1596
.40	.1877
.45	.2166
.50	.2463
.60	.3081
.70	.3727
.80	.4399
.90	.5094
1.00	.5810
2.00	1.3935

TABLE 5- 1 WATER AND SEDIMENT CARRYING CAPACITIES
FOR A CULVERT 36. INCHES IN DIAMETER
SEDIMENT SIZE= .400 MM

SLOPE	Q(CFS)	QS(LBS/SEC)
.001	10.97	.45
.002	15.51	3.66
.005	24.52	58.27
.007	29.02	160.97
.010	34.68	472.65